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NonLinear Effects of Inflation on Economic Growth

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Abstract

This paper examines the possibility of nonlinear effects of inflation on economic growth. It finds evidence of a significant structural break in the function that relates economic growth to inflation. The break is estimated to occur when the inflation rate is 8 percent. Below that rate, inflation does not have any effect on growth, or it may even have a slightly positive effect. When the inflation rate is above 8 percent, however, the estimated effect of inflation on growth rates is significant, robust and extremely powerful. The paper also demonstrates that when the existence of the structural break is ignored, the estimated effect of inflation on growth is biased by a factor of three.

JEL Classification Numbers:

E31, O40

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Summary

It is now widely accepted that inflation has a negative effect on economic growth. This negative effect, however, was not detected in data from the 1950s and the 1960s. Until the 1970s, many studies found this effect to be nonsignificant, or even positive. The change in view came only after many countries experienced severe episodes of high and persistent inflation in the 1970s and the 1980s. As more data became available on these episodes, studies confirmed repeatedly that inflation has a significant negative effect on economic growth.

The abrupt change in the view regarding the effects of inflation on growth raises three important questions: (i) Why did it take so long and so many studies to uncover such an obvious link between two of the most important and most closely watched macroeconomic variables? (ii) As the estimated effect of inflation on growth is relatively small, should the results of these studies affect policy priorities and institutional arrangements? and (iii) If a specific range for inflation is adopted as a policy target, what should this range be?

Motivated by these questions, this paper explores the possibility of nonlinear effects of inflation on economic growth. It finds evidence of the existence of a structural break in the function that relates growth rates to inflation. When inflation is low, it has no significant negative effect on economic growth; the effect may even be slightly positive. But when inflation is high, it has a powerful negative effect on growth. The structural break is estimated to occur where the average annual rate of inflation is 8 percent.

The existence of such a structural break can explain why the negative effect of inflation on economic growth was not detected for such a long time: before the 1970s, there were not many episodes of high inflation. It also suggests a specific numerical target for policy: keep inflation always below the structural break. Most important, the existence of a structural break implies that previous studies seriously underestimated the negative effects on economic growth of higher rates of inflation. This study demonstrates that when the existence of the structural break is ignored, the estimated effect of inflation on economic growth for the higher rates of inflation decreases by a factor of three. Taking the structural break into account, the paper finds evidence that the effects of inflation on growth are much more powerful than previous studies had estimated.

I. Introduction

It is now widely accepted that inflation has a negative effect on economic growth. This negative effect, however, was not detected in the data from the 1950s and the 1960s. Based on that data, the view that prevailed in the economic profession was that the effects of inflation on growth are not particularly important. Until the 1970s, many studies found the effect to be nonsignificant. Moreover, some found a positive effect of inflation on growth. In general, the empirical evidence was, at best, mixed. 1/ The change came only after many countries experienced severe episodes of high and persistent inflation, in the 1970s and the 1980s. These high-inflation episodes were usually associated with a general decline in the macroeconomic performance and with balance of payments crisis. As more data became available about these episodes, studies confirmed again and again that inflation has a negative effect on economic growth. 2/ Although this effect was shown to be statistically significant, its magnitude is not impressive. But still, it is one of the very few variables, influenced by macroeconomic policy, that were found to affect the growth rates. As a result, the dominant view regarding the effects of inflation changed radically. Now, many economists are convinced that inflation is undesirable and it should be totally avoided. They propose policy measures and institutional changes to guarantee low inflation. One favorite proposal is to establish independent central banks with a clear mandate to keep inflation levels within a specific range, usually defined as consistent with price stability. Such proposals were adopted in New Zealand and in Canada, and are being discussed in many other countries.

The abrupt change in the view about the effects of inflation on growth raises three important questions: (i) what is the reason that it took so long and so many studies to uncover such an obvious link between two of the most important and most closely watched macroeconomic variables?; (ii) the estimated effect of inflation on growth being relatively small, should it really affect policy priorities and institutional arrangements?; and (iii) if a specific range for inflation is indeed adopted as a target and is included in a legislative measure, what should this range be?

Motivated by these questions, this paper explores the possibility of nonlinear effects of inflation on economic growth. In Section II it presents the data that is used in the regressions. In Section III it

1/ This is documented, for example, by Bruno and Easterly (1994). They write: "Johnson in (1967) suggested that there was no conclusive empirical evidence one way or the other - as a series of studies in the IMF Staff Papers around that time bear witness (Tun (1959), Dorrance (1963, 1966) and Bhatia (1960)). Even for Latin America, where higher double-digit rates of inflation were experienced during that period, the evidence well into the 1970s was ambiguous (Pazos (1972); Galbis (1979))".

2/ There are many studies that found support for this view. Some of the latest are Smyth (1994), Sbordone and Kuttner (1994), De Gregorio (1993), Fischer (1993) and De Gregorio (1992).

performs a preliminary test, in order to uncover the general shape of the function that relates growth rates to inflation. This test involves estimating the effects of twelve inflation groups on growth. The results of this preliminary test raise the possibility that the function contains a structural break.

The existence of such a structural break can explain why the negative effect of inflation on economic growth was not detected for such a long time: before the 1970s, there were not many episodes of high inflation. It also suggests a specific numerical target for policy: keep inflation always below the structural break. Most importantly, it implies that previous studies seriously underestimated the negative effects of inflation on economic growth, when inflation is relatively high. If a structural break exists, failing to take it into account introduces a significant bias in the estimated effect of inflation.

Section IV performs the main test, in order to estimate the point of the structural break, its significance, and the two inflation effects, below and above the structural break. Section V performs additional tests, as variations to the main test. Section VI presents concluding remarks and policy implications.

II. The Data

This study uses data on population, GDP, consumer price indices, terms of trade, real exchange rates, government expenditures and investment rates. Two databases are used as inputs for this study, the "PWT 5.5" database and the "World Tables" database. ^{1/}

The CPI and the terms of trade data are used in order to reduce the problem of negative correlation between inflation and growth rates, that is not directly caused by inflation effects on growth. It is better to use CPI data than implicit GDP deflators, in this type of study, because changes in GDP deflators are, by construction, negatively correlated with the growth

^{1/} The "PWT 5.5" is an NBER update to "PWT 5.0", a database described by Summers and Heston (1991). The "World Tables" database is an on-line database of the World Bank. Most of the variables are from the first database: annual data on population, output per person, government expenditures as percent of GDP and investment as percent of GDP, all measured in PPP 1985 dollars. Annual data on consumer prices and on terms of trade indices are extracted from the second database.

rates. 1/ The terms of trade are used in order to eliminate the negative correlation between growth and inflation that is caused by external supply shocks. 2/

Combining the two databases, a joint panel database is produced. This database contains continuous annual information for 87 countries, during the period 1970-90. 3/ The 20-year sample period is divided into four equal periods of five years each, obtaining a total of 248 observations. 4/ For each 5-year period, between the year t and the year $t+5$, the growth rates of output per person, population growth rates, inflation rates and rates of

1/ Suppose, for example, that there are two periods and a measurement error overestimates the output volume in the second period. In this case, the growth rate between the two periods will be overestimated, while the change in the implicit GDP deflator between the two periods will be underestimated. If the output volume is underestimated in the second period, the growth rate between the two periods will be underestimated, while the change in the implicit GDP deflator between the two periods will be overestimated. In both cases, the measurement error will induce a negative correlation between real growth rates and GDP deflators. Because CPI indices are calculated independently of output volume, their use should avoid this problem.

2/ Negative external supply shocks, such as an increase in oil prices in the case of industrialized countries, tend to increase inflation and to reduce growth, inducing a negative correlation between the two variables. Positive shocks increase growth and reduce inflation, again inducing a negative correlation between the two variables. Fischer (1993) recognizes this problem. He writes: "The inclusion of changes in the terms of trade as a regressor goes a long way towards dealing with this problem". This study follows his advice and always controls for changes in the terms of trade.

3/ The complete list of countries is presented in the Appendix. For some of the countries, the "PWT 5.5" database does not contain observations for the year 1990, the last year of observations for these countries being 1989. In these cases, data on GDP, GDP deflators and population for the years 1989 and 1990 are extracted from the "World Tables" database. Then, this data is used in order to calculate the growth rates of real income per person and of population between 1989 and 1990. These rates are used to extend the "PWT 5.5" database to 1990. This procedure is applied for the following 12 countries: Barbados, Ghana, Haiti, Iran, Jamaica, Korea, Malta, Myanmar, Niger, Seychelles, Sri Lanka and Suriname.

4/ Dividing the sample period into smaller periods has two advantages. First, it increases the number of observations. Second, it introduces a time dimension, making possible to estimate country-specific effects. Making the sub-periods too short, however, may cause problems related to business cycles and their effects on inflation. The division to 5-year periods is chosen as a compromise and it also follows a standard practice in the empirical literature on economic growth.

change in the terms of trade are being defined as the average logarithmic annual changes during the period: 1/

$$growth(t, t+5) = \frac{\log (y_{t+5} / y_t)}{5} \quad (1)$$

$$n(t, t+5) = \frac{\log (pop_{t+5} / pop_t)}{5} \quad (2)$$

$$\Pi(t, t+5) = \frac{\log (P_{t+5} / P_t)}{5} \quad (3)$$

$$\Delta TOT(t, t+5) = \frac{\log (TOT_{t+5} / TOT_t)}{5} \quad (4)$$

An interesting (but not so important) question is how to treat the observations with a negative inflation rate. One possibility is to argue that the effect of inflation around 0 is monotonic, and therefore to leave these observations as they are. Another possibility is to argue that what really matters for growth is price stability, and the relevant variable is the absolute value of inflation (or some monotonic transformation of that value). A third possibility is to ignore these observations altogether. Finally, the fourth possibility is to treat these observations just as being close to 0, as a compromise between the first two approaches. This study chooses to take this last approach and substitutes an inflation rate of 0.1 percent for the negative observations. 2/

A less interesting question (but a more important one) is whether it is better to use a transformation of the inflation rate than simply to use the rate itself. Figures 1 and 2 present, respectively, the histograms of the distribution of the inflation rate and of its logarithmic transformation. As these figures make clear, the rate of inflation has a very asymmetric distribution (the lowest 1/10 of its range contains 88 percent of the observations). Using this variable would place an enormous weight on the very few observations with the highest inflation

1/ When inflation is small, a logarithmic (continuous) rate is very similar to a discrete rate. But the two differ when inflation is high. A logarithmic rate of 50 percent, for example, corresponds to a cumulative discrete rate of 65 percent from one year to the next. All the rates discussed in this paper are annual averages of logarithmic rates.

2/ The reason this problem is not very important is that the sample used in this study contains only two observations of negative inflation. Both observations occur in the period 1985-90: Burkina Faso (-0.5 percent) and Niger (-3.1 percent). The chosen corrective value of 0.1 percent corresponds to the smallest positive inflation observation in the sample.

Figure 1
The Distribution of Inflation

of observations

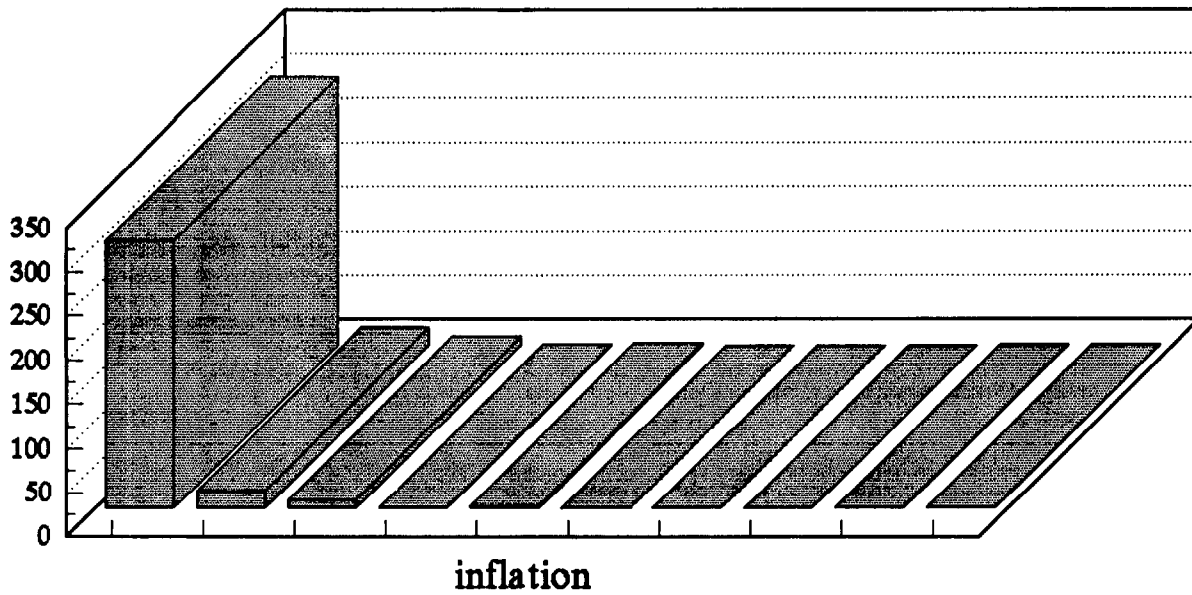
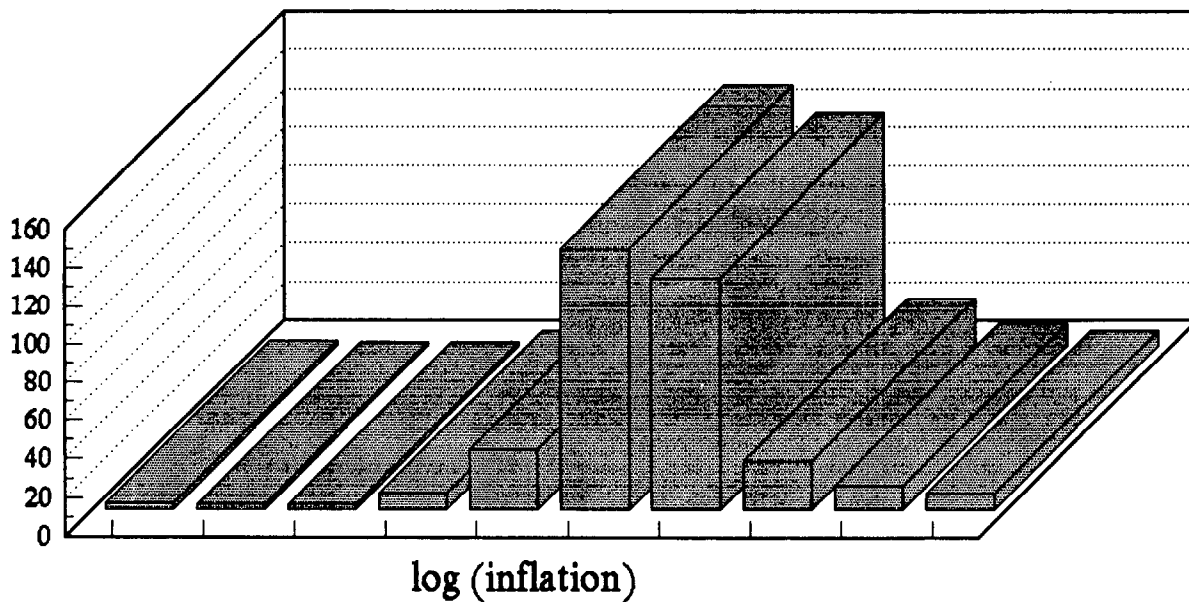


Figure 2
The Distribution of the Log of Inflation

of observations



rate. The logarithm of inflation, on the other hand, has a much more balanced distribution. In the remaining of this paper, the logarithmic transformation of the inflation rate will be used.

III. A Preliminary Test

This section makes a first attempt to uncover nonlinear features in the function that relates economic growth to inflation. In order to find the general shape of this function, it first divides the 348 inflation observations into 12 equal groups of 29 observations each. The groups contain increasingly higher inflation observations. 1/ Each inflation group, except Group 6, is assigned a dummy variable.

Then, an OLS regression is estimated for the growth rate on the inflation dummies, on country dummies (except the first country, Algeria), on period dummies (except the first period, 1970-75) and on the other explanatory variables that are usually used in growth regressions, such as the log of initial income per person (*LY*), population growth rate (*N*), government expenditures as a percent of GDP (*GOV*) and the rate of change in the terms of trade (ΔTOT). 2/

The results of the regression (except the estimated coefficients for the country and the period dummies) are presented in Table 1, Regression 1. An F-test rejects at 1 percent confidence level the hypothesis that the 86 country dummies are 0. This rejection implies that country-specific effects are important in explaining the growth rates. The same is true about an F-test for the 3 period dummies. Nevertheless, Regression 2 in Table 1 presents the results of a regression that does not include country dummies and period dummies. The estimated coefficients of the different inflation groups represent the effect on growth of each group, relative to group 6, which is used as reference. 3/

1/ Group 1, for example, contains inflation rates of less than 3.8 percent, while Group 12 contains inflation rates in excess of 39.3 percent.

2/ The regressions in this section, as well as the regressions in the rest of this paper, basically confirm the stylized facts about the determinants of economic growth, as documented by many other studies, such as Barro (1991). The growth rate of income per person depends negatively on initial income, on the population growth rate and on government expenditures and depends positively on changes in the terms of trade. Because this study concentrates on the effects of inflation on growth, the results concerning the other variables will not be further discussed.

3/ A word of caution: here, as well as in the other sections of this paper, the results of the regressions are interpreted as measuring the marginal effects of inflation on economic growth. This interpretation has a long tradition, and has strong and direct policy implications, but is certainly not the only possible one. Levine and Zervos (1993), among others, raise important questions about this kind of interpretation.

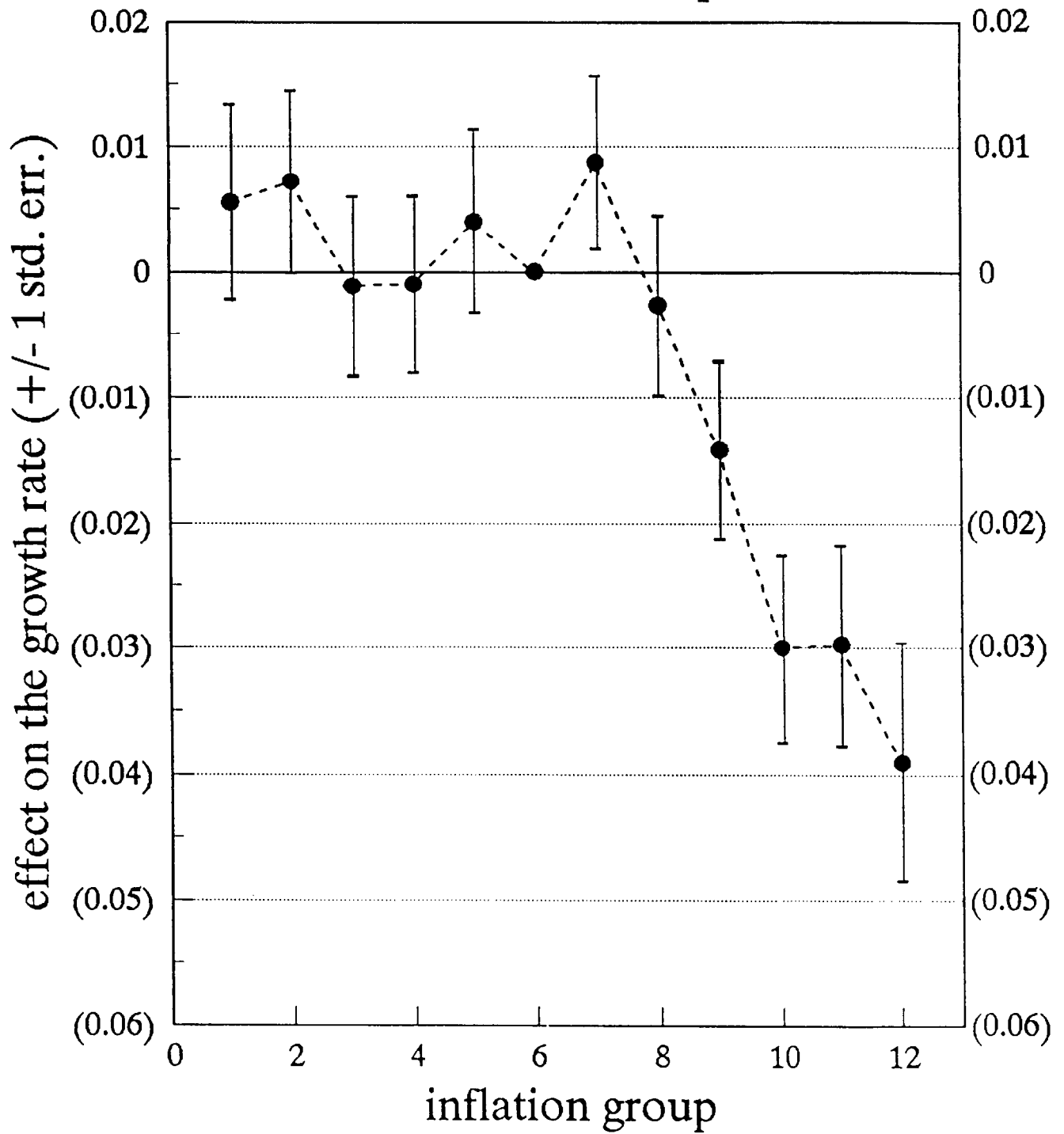
Table 1. The Estimated Coefficients of the Inflation Groups

	1	2
Country and Year Dummies	Yes	No
Adjusted R ²	0.493	0.148
C	0.504 (7.09)	0.0943 (3.95)
LY	-0.0641 (-6.95)	-0.00556 (-2.33)
N	-0.113 (-0.306)	-0.700 (-3.51)
GOV	-0.00103 (-1.47)	-0.000755 (-3.03)
ΔTOT	0.0841 (3.27)	0.0822 (2.77)
GR1	0.00554 (0.708)	0.00265 (0.335)
GR2	0.00718 (0.986)	0.000122 (0.0155)
GR3	-0.00115 (-0.161)	-0.00609 (-0.775)
GR4	-0.00101 (-0.144)	-0.00610 (-0.777)
GR5	0.00401 (0.547)	-0.00213 (0.271)
GR7	0.00872 (1.26)	0.0110 (1.41)
GR8	-0.00270 (-0.376)	-0.000605 (-0.0772)
GR9	-0.0142 (-2.01)	-0.0102 (-1.30)
GR10	-0.0300 (-4.05)	-0.0239 (-3.04)
GR11	-0.0298 (-3.73)	-0.0147 (-1.87)
GR12	-0.0390 (-4.14)	-0.0252 (-3.21)

Notes: (1) The dependent variable is the average growth rate of output per person. (2) The number of observations is 348. (3) The method of estimation is OLS. (4) t-statistics are reported in parenthesis. (5) Regression 1 does not report 86 country-dummies and 3 period-dummies.

Figure 3 describes the estimated coefficient and the corresponding standard error for each inflation group, as reported by Regression 1.

Figure 3
Effects of Different Inflation Groups on Growth



An important feature of the data emerges in the results presented in Table 1 and in Figure 3: the effects of inflation on economic growth may contain a structural break. When inflation is low, there are no significant differences in the coefficients of different inflation groups. In other words, it does not make any significant difference for the growth rates if inflation is low, very low, or zero. When inflation is high, on the other hand, moving to a higher inflation group has a dramatic impact on the growth rates. For example, the difference in the effect on growth rates between the highest inflation group and Group 6 is estimated to be close to 4 percentage points. This is more than twice the average growth rate in the sample.

IV. The Main Test

The previous section presented evidence that the function that relates economic growth to inflation may contain a structural break. This finding raises at least three questions:

- (i) At what level of inflation does the structural break occur?
- (ii) Is the break significant? 1/
- (iii) What are the two estimated values of the inflation effects on growth?

This section answers these three central questions, using a simple estimation technique. First, it defines:

Π^* = the rate of inflation at which the structural break occurs.
 $DD = 1$ if $\Pi > \Pi^*$, 0 otherwise.
 $EXTRA = DD (\text{Log} (\Pi) - \text{Log} (\Pi^*))$.

Then, an OLS regression is estimated for the growth rate on the two variables $\text{Log} (\Pi)$ and $EXTRA$, in addition to the usual explanatory variables. When inflation is low ($\Pi < \Pi^*$), $EXTRA = 0$ (by construction) and the effect of inflation on growth is estimated by the coefficient of $\text{Log} (\Pi)$. However, when inflation is high ($\Pi > \Pi^*$), the relevant estimator is the sum of two coefficients: the coefficient of $\text{Log} (\Pi)$ and the coefficient of $EXTRA$. The coefficient of $EXTRA$ estimates the difference in the inflation effect on growth between the two sides of the structural break, and its t-statistic value tests whether the structural break is significant or not. 2/

1/ In other words, is the effect of inflation on growth significantly different above the structural break than it is below the structural break?

2/ A similar spline function was estimated by Fischer (1993). Fischer divides his observations into three arbitrary groups (Table 8 in his paper). His variables are defined differently than the ones used in this study, and the technique he uses also is different. Using his specific division, he did not find significant effects of inflation on growth, for any of the inflation groups, although he found evidence of negative effects in the whole sample.

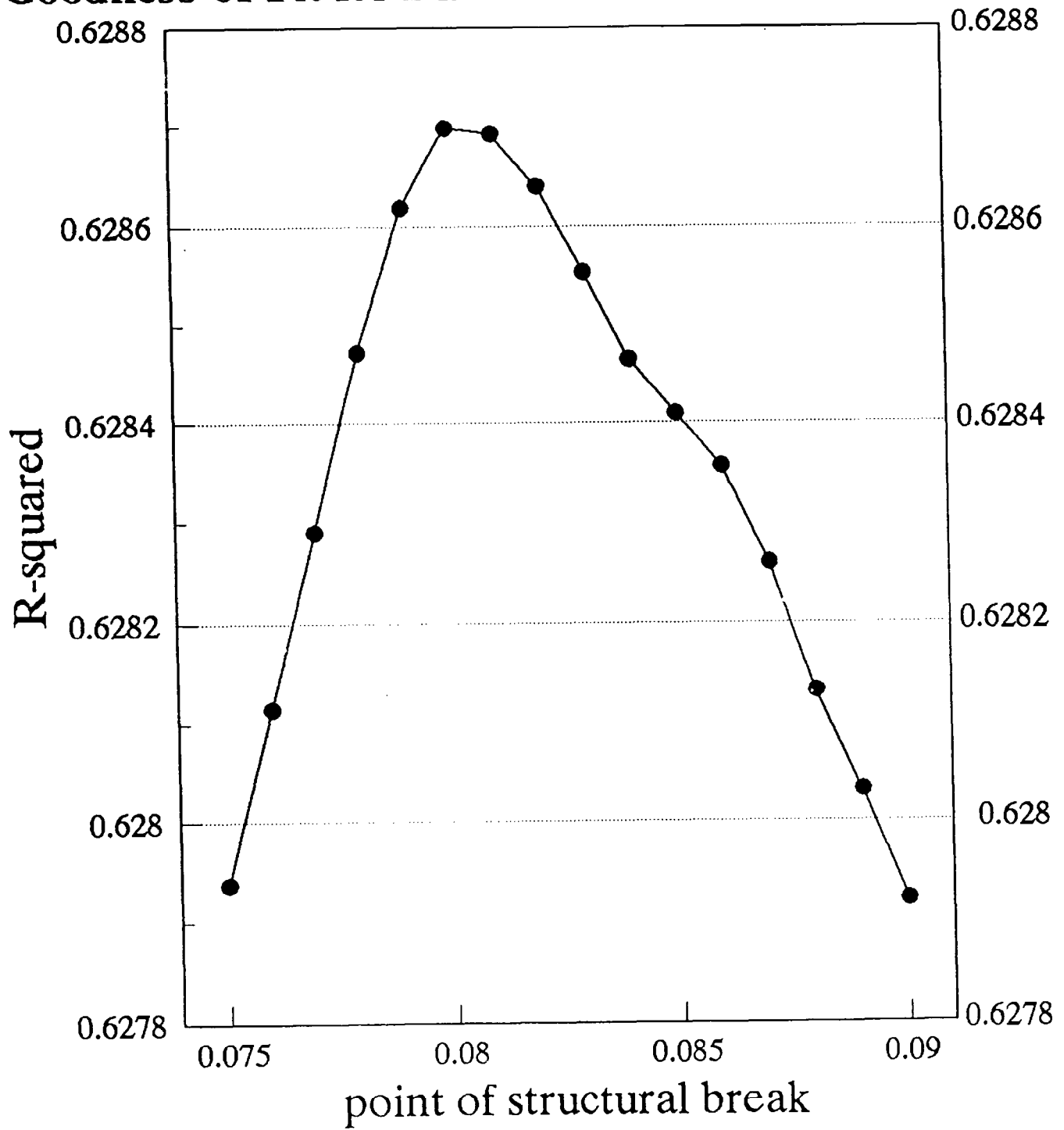
We are now in a position to answer the second and the third questions raised in the beginning of this section, but we still have to find at what level of inflation the structural break occurs. Assuming that the error variance is equal for the entire inflation range, we can estimate the regression for different values of Π^* and choose, as the breakpoint, the value of Π^* that minimizes the sum-of-squared residuals from the regression. This is equivalent to picking the Π^* that maximizes R^2 . Figure 4 presents the results of iterating the regression for different values of Π^* . It shows that the value of R^2 is maximized when $\Pi^* = 8.0$ percent.

Regression 1 in Table 2 assumes a value of 8 percent for Π^* . The last row of the table calculates the implied effect of inflation when $\Pi > \Pi^*$. Using the variance-covariance matrix of the regression's coefficients, we also calculate the standard error of this effect and report its t-statistic. The results of Regression 1 confirm that there is indeed a significant structural break at an inflation level of 8 percent. The t-statistic for *EXTRA* makes possible to reject at the 1 percent confidence level the hypothesis of equal effects of inflation (below and above 8 percent). When the inflation rate is less than 8 percent, its effect is positive, but very weak and statistically insignificant. On the other hand, the effect of inflation when $\Pi > 8$ percent is not only significant at 1 percent confidence level, but also extremely powerful. The coefficient of -0.0248 for $\text{Log } \Pi$ can be interpreted to mean that the annual growth rate decreases by 1.7 percentage points (the equivalent of the average growth rate in the sample) when the inflation rate doubles. The results of the regression also confirm our prior expectations about the other included variables.

Regression 2 reports, for comparison, the results in the case where the *EXTRA* variable is not included. It demonstrates how not taking into account the existence of the structural break makes a huge impact on the estimated effect of inflation on economic growth. By not including the variable *EXTRA* as a regressor, Regression 2 estimates the effect of inflation on economic growth, conditional on this effect being the same over all the inflation spectrum. In the case of high inflation ($\Pi > \Pi^*$), the estimated effect of inflation in Regression 2 is only one-third compared to the effect estimated by Regression 1. Another look at Figure 3 provides a simple intuition for this important result: when $\Pi > \Pi^*$, Regression 1 estimates the slope of the function that relates economic growth to inflation, but only for the range of inflation where this slope is steep. Regression 2, on the other hand, estimates an average slope over all the inflation spectrum, including the range where the slope of the function is close to 0 or even slightly positive. Therefore, a large bias occurs in the estimated effect of inflation in Regression 2, as well as in all the other studies that ignore the existence of the structural break.

The country dummies group and the period dummies group are both significant at the 1 percent confidence level. However, we also look at the case when these dummies are not included. In this case, the Π^* that maximizes R^2 is 10.1 percent. Regression 3 does not include dummies and assumes that $\Pi^* = 10.1$ percent. It reports results that are very similar

Figure 4
Goodness-of-Fit for Different Structural Breaks



to the results of Regression 1. The main difference is that the negative effect of inflation above Π^* is about 35 percent weaker than in Regression 1 (but still twice the estimate of Regression 2).

Table 2. The Regressions for the Main Test

	1	2	3
Country and Year Dummies	Yes	Yes	No
Assumes a structural break	Yes	No	Yes
Estimated point of the structural break	0.080		0.101
Adjusted R ²	0.491	0.435	0.148
C	0.551 (7.81)	0.467 (6.44)	0.0910 (3.79)
LY	-0.0672 (-7.39)	-0.0595 (-6.29)	-0.00487 (-2.07)
N	-0.516 (-1.44)	-0.560 (-1.48)	-0.675 (-3.44)
GOV	-0.000936 (-1.38)	-0.000887 (-1.24)	-0.000730 (-2.93)
ΔTOT	0.0853 (3.37)	0.0778 (2.92)	0.0835 (2.87)
LOG (Π)	0.00277 (0.964)	-0.00821 (-3.87)	0.00160 (0.611)
EXTRA	-0.0276 (-5.38)		-0.0176 (-4.02)
Estimated coefficient of log Π for high inflation	-0.0248 (-3.33)	-0.00821 (-3.87)	-0.0160 (-2.42)

Notes: (1) The dependent variable is the average growth rate of output per person. (2) The number of observations is 348. (3) The method of estimation is OLS. (4) t-statistics are reported in parenthesis. (5) Regressions (1) and (2) do not report 86 country-dummies and 3 period-dummies.

V. Additional Tests

This section performs additional tests as variations to the main test. One reason for these additional tests is to increase our understanding about the effects of inflation on economic growth. A second reason is to use changes in the specifications of the regression to check the robustness of the earlier results, regarding the nonlinear effects of inflation on economic growth.

Table 3 presents results of regressions that use only observations from the last 3 periods (1975-90). These regressions assume that the structural break occurs when the rate of inflation is 8 percent. Regression 1, that presents the basic results, is the equivalent of Regression 1 in Table 2. The results here confirm our previous conclusions. The main difference is that the estimated effect of inflation when $\Pi > 8$ percent is weaker than before (although the structural break remains significant). Regressions 2 and 3 in Table 3 include, respectively, $\text{Log}(\Pi)$ lagged for one period and first-differences in $\text{Log}(\Pi)$. The estimated coefficients of these variables are not significant. Changes in the inflation rate, at least between the 5-year periods used in this study, do not appear to have any effect on growth. Also, including these additional variables does not have any significant effect on the estimated coefficients of the other variables in the regression.

Table 3. Lagged Inflation

	1	2	3
Adjusted R ²	0.553	0.551	0.551
C	0.664 (7.56)	0.666 (7.47)	0.666 (7.47)
LY	-0.0782 (-7.01)	-0.0786 (-6.83)	-0.0786 (-6.83)
N	-1.19 (-2.69)	-1.19 (-2.69)	-1.19 (-2.69)
GOV	-0.000910 (-1.07)	-0.000919 (-1.08)	-0.000919 (-1.08)
ΔTOT	0.0787 (2.25)	0.0781 (2.21)	0.0781 (2.21)
$\text{LOG}(\Pi)$	0.00397 (1.25)	0.00405 (1.24)	0.00354 (0.782)
EXTRA	-0.0212 (-3.49)	-0.0212 (-3.47)	-0.0212 (-3.47)
$\text{LOG}(\Pi_{-1})$		-0.000519 (-0.136)	
$\text{LOG}(\Pi) - \text{LOG}(\Pi_{-1})$			0.000519 (0.136)
Estimated coefficient of $\log \Pi$ for high inflation	-0.0172 (-2.02)	-0.0171 (-2.00)	-0.0177 (-1.93)

Notes: (1) The dependent variable is the average growth rate of output per person. (2) The number of observations is 261. (3) The method of estimation is OLS. (4) t-statistics are reported in parenthesis. (5) 86 country-dummies and 2 period-dummies are not being reported.

Table 4 again uses all 4 periods, and includes additional explanatory variables. Regression 1 presents the basic results (reported previously in Table 2, Regression 1). Regression 2 includes the investment rate (as percent of GDP, measured in PPP 1985 dollars). Including the investment rate may identify how inflation affects growth. If inflation reduces growth only indirectly, by reducing capital accumulation, we would expect to find a much weaker direct inflation effect, once the investment rate is included as an explanatory variable. But the results of Regression 2 demonstrate that, even controlling for the investment rate, the inflation coefficient remains strong and significant, and it retains about 88 percent of its previous value. One possible interpretation of this result is that inflation affects growth mainly through its harmful effect on efficiency and productivity. Regression 3 includes the real exchange rate, defined as the average deviation from PPP in the dollar price of GDP, compared to the United States (based on the data in PWT 5.5). The real exchange rate does not have any significant effect on growth and its inclusion does not change in any way the estimated effect of inflation on growth.

Table 4. Additional Variables

	1	2	3
Adjusted R ²	0.491	0.525	0.489
C	0.551 (7.81)	0.597 (8.67)	0.545 (7.51)
LY	-0.0672 (-7.39)	-0.0788 (-8.59)	-0.0666 (-7.21)
N	-0.516 (-1.44)	-0.659 (-1.89)	-0.513 (-1.43)
GOV	-0.000936 (-1.38)	-0.000879 (-1.34)	-0.000916 (-1.34)
ΔTOT	0.0853 (3.37)	0.0936 (3.81)	0.0858 (3.38)
LOG (Π)	0.00277 (0.964)	0.00199 (0.716)	0.00250 (0.848)
EXTRA	-0.0276 (-5.38)	-0.0239 (-4.78)	-0.0273 (-5.28)
INV		0.00170 (4.41)	
RER			-0.00355 (-0.391)
Estimated coefficient of log Π for high inflation	-0.0248 (-3.33)	-0.0219 (-3.03)	-0.0248 (-3.28)

Notes: (1) The dependent variable is the average growth rate of output per person. (2) The number of observations is 348. (3) The method of estimation is OLS. (4) t-statistics are reported in parenthesis. (5) The regressions do not report 86 country-dummies and 3 period-dummies.

Table 5 repeats the procedure from Table 2, using the same raw data, but dividing the observations differently. Now, instead of 4 periods of 5 years each, the data is divided into 5 periods of 4 years each, for a total of 435 observations.

Table 5. Four-Year Periods

	1	2	3
Country and Year Dummies	Yes	Yes	No
Assumes a structural break	Yes	No	Yes
Estimated point of the structural break	0.079		0.063
Adjusted R ²	0.454	0.364	0.160
C	0.574 (8.53)	0.473 (6.64)	0.113 (4.94)
LY	-0.0660 (-7.51)	-0.0566 (-6.03)	-0.00511 (-2.35)
N	-0.850 (-2.60)	-0.871 (-2.47)	-0.642 (-3.57)
GOV	-0.00171 (-2.71)	-0.00151 (-2.22)	-0.000803 (-3.48)
ΔTOT	0.0415 (2.33)	0.0334 (1.74)	0.0420 (2.02)
LOG (Π)	0.00546 (2.43)	-0.00589 (-3.25)	0.00645 (2.66)
EXTRA	-0.0335 (-7.57)		-0.0224 (-6.03)
Estimated coefficient of log Π for high inflation	-0.0280 (-4.55)	-0.00589 (-3.25)	-0.0160 (-2.72)

Notes: (1) The dependent variable is the average growth rate of output per person. (2) The number of observations is 435. (3) The method of estimation is OLS. (4) t-statistics are reported in parenthesis. (5) Regression 1 does not report 86 country-dummies and 4 period-dummies.

The results reported in the three regressions of Table 5 should be compared with the results reported in Table 2, for the case of 5-year periods. The results here confirm all the previous conclusions. In particular, they confirm the existence of a significant structural break. Also, its estimated point in Regression 1 (7.9 percent) is very close to the previous estimate (8.0 percent). The results of Table 5 also reinforce the conclusion that ignoring the existence of the structural break has a huge effect on the estimated effect of inflation. Now, this estimated effect decreases in Regression 2 (compared to Regression 1) by a factor of 5! There is one notable exception, however: the positive effect of inflation at low levels of inflation is now statistically significant.

VI. Conclusions and Policy Implications

This paper explored the possibility of nonlinear effects of inflation on economic growth. It found evidence of the existence of a structural break in the function that relates growth rates to inflation. It found that when inflation is low, it has no significant negative effect on economic growth. The effect may even be slightly positive. But when inflation is high, it has a negative effect on growth. This negative effect is robust, statistically significant and very powerful. The point of the structural break was estimated to occur where the average annual rate of inflation is 8 percent.

If a structural break exists, failing to take it into account introduces a significant bias in the estimated effect of inflation. This study demonstrated that when the structural break is taken into account, the estimated effect of inflation on economic growth increases by a factor of three. The existence of such a structural break also suggests a specific numerical target for policy: keep inflation always below the structural break.

One possible interpretation of the empirical results of this paper is that when the inflation rate doubles (for example, a relatively moderate increase in inflation from 20 percent to 40 percent), the growth rate decreases by 1.7 percentage points. This difference of 1.7 percentage points is much higher than previous studies had estimated, and is exactly equal to the average growth rate of income per person in the last two decades. In other words, it is the difference between sustained growth and stagnation. This interpretation implies that a macroeconomic policy to avoid high inflation is one of the best recommendations economists can make.

APPENDIX

The Complete List of Countries

	COUNTRY		COUNTRY		COUNTRY
1	Algeria	30	Guatemala	59	Pakistan
2	Argentina	31	Guyana	60	Panama
3	Australia	32	Haiti	61	Paraguay
4	Austria	33	Honduras	62	Peru
5	Bangladesh	34	Hong Kong	63	Philippines
6	Barbados	35	Iceland	64	Poland
7	Bolivia	36	India	65	Portugal
8	Brazil	37	Indonesia	66	Senegal
9	Burkina Faso	38	Iran, I.R. of	67	Seychelles
10	Burundi	39	Ireland	68	Sierra Leone
11	Canada	40	Israel	69	Singapore
12	Chile	41	Italy	70	South Africa
13	China	42	Jamaica	71	Spain
14	Colombia	43	Japan	72	Sri Lanka
15	Congo	44	Jordan	73	Suriname
16	Costa Rica	45	Kenya	74	Sweden
17	Côte d'Ivoire	46	Korea, Rep. of	75	Switzerland
18	Cyprus	47	Madagascar	76	Syria
19	Denmark	48	Malaysia	77	Thailand
20	Dominican Rep.	49	Malta	78	Togo
21	Ecuador	50	Mauritius	79	Trinidad and Tobago
22	Egypt	51	Mexico	80	Tunisia
23	Fiji	52	Morocco	81	Turkey
24	Finland	53	Myanmar	82	United Kingdom
25	France	54	Netherlands	83	United States
26	Gambia	55	New Zealand	84	Uruguay
27	Germany, West	56	Niger	85	Venezuela
28	Ghana	57	Nigeria	86	Zambia
29	Greece	58	Norway	87	Zimbabwe

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